U.S. BUREAU OF MINES, HELIUM PLANTS, AMARILLO HELIUM PLANT
10001 Interchange 552
Amarillo
Potter County
Texas

HAER TX-105-A
HAER TX-105-A

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

HISTORIC AMERICAN ENGINEERING RECORD
SOUTHWEST SYSTEM SUPPORT OFFICE
National Park Service
U.S. Department of the Interior
PO Box 728
Santa Fe, NM 87504

HISTORIC AMERICAN ENGINEERING RECORD

U.S. Bureau of Mines, Helium Plants, Amarillo Helium Plant

HAER No. TX-105-A

Location: 10001 Interchange 552, Amarillo, Potter County, Texas

Date of Construction: 1928-1943

Present Owner: Bureau of Land Management, Department of Interior

Present Use: Closed (1998)

Significance: An inert, nonflammable gas, helium became a strategically important element after the U.S. Navy began producing it in 1917. Since then, helium has been used in lighter-than-air craft, as well as rocketry, aerospace technology, tbe medical field, science and industrial construction, and for the more mundane purpose of inflating balloons. For many decades, the United States maintained a monopoly on helium, giving the nation an edge in atomic science and the space race. Helium played a key role during World War II because of its use in blimp reconnaissance on the high seas and as an element in the atomic bomb. After the war, helium served as a key element in the National Aeronautics and Space Administration's (NASA) Cold War activities. The U.S. Bureau of Mines' Amarillo Helium Plant, built in 1928-29, served as headquarters for the government's helium program, as well as the place where the technology for processing, producing, and shipping helium was developed. In 1942-43, with rapidly expanding military needs, the government constructed a second helium plant, Exell, at Masterson, Texas. After the war, Exell became the leading producer of helium in the United States and the world. With passage of the Helium Conservation Act of 1960, the principal focus of helium production shifted from the federal government to private industry, culminating in 1996 with passage of the Helium Privatization Act. In 1998, the Exell and Amarillo plants closed. Over the years, a somewhat primitive technology that produced 97 percent helium in the 1920s, advanced to a sophisticated international industry producing 99.999999 percent and higher grade helium.

Historian: Christopher J. Huggard

Project Information: Field work, measured drawings, historical reports and photographs were prepared under the direction of the National Park Service, Intermountain Support Office, Santa Fe, with assistance from John Litchfield, chief of closure operations, Amarillo, Texas. The recording team comprised supervisory architect Barry Sulam, American Institute of Architects; project leaders Joseph Thomas (Montana State University) and Todd Delyea (University of Idaho); and architects Lucas Dupuis, Thomas Cheney, and Dominggus Paliling (Montana State University), Joe Snider (University of Oregon), Suzanne Rowe Covington (Cal State Polytechnic), and Jon Gamel (Texas Tech University). Art Gomez, Ph.D., regional historian, Intermountain Region Support Office, National Park Service, Santa Fe, assisted by Christopher Huggard, Ph.D., (Northwest Arkansas Community College) provided the historical research and written narrative. John S. Hanttula completed the formal photography.

Chronology

1917	United States first nation to produce helium
1919	U.S. Bureau of Mines constructed Fort Worth, Texas, helium plant
1921	Cliffside gas field discovered in Texas Panhandle
1925	Congress passed the Helium Conservation Act of 1925 transferring authority for the helium program from the U.S. Navy to the U.S. Bureau of Mines, Department of Interior
1926	Bureau of Mines decided to close the Fort Worth plant in favor of a new plant at Amarillo, Texas, near the Cliffside gas field
1929	Amarillo plant construction completed, Cryogenic Research Laboratory moved from Washington, D.C., to Amarillo
1937	Congress passed the Helium Act of 1937 and the passenger airship *Hindenburg* crashed at Lakehurst, New Jersey
1941-1943	Exell helium plant constructed 35 miles north of Amarillo plant
1945	Bureau of Mines began storing crude helium underground in the Cliffside field, heliarc welding method invented
1946	Engineers at the Amarillo and Exell plants began experimenting with the charcoal purification process used to produce purer grades of helium
1949	Bureau of Mines began producing for consumption Grade A (99.995 percent or purer) helium
1953-1958	Helium shortage due to Cold War demands of aerospace industry and a limited production capacity of the government helium operations
1956	Bureau of Mines expanded helium production capacity at the Exell plant to meet national defense needs for the inert gas
1960	Congress passed the Helium Conservation Act of 1960
1968	Exell Instrumentation Project completed giving bureau engineers computerized control of the operations

1978-90	Exell technology upgraded
1996	Congress passed the Helium Privatization Act of 1996
1998	Federal government production & sale of refined Helium terminated

History and Technology, 1917-1996

The history of the U. S. Bureau of Mines helium plants in the Texas Panhandle is inextricably woven into the history of helium. An inert, nonflammable gas, helium has been a strategically important element since the Navy began producing it in 1917. Since that time, government chemists and engineers and others have discovered ways to use helium in lighter-than-air craft, as a key element in aerospace technology, in the medical field, in rocketry construction and science and industrial construction, for the more mundane purpose of inflating balloons, and other uses. Helium played a key role during World War II because of its role in blimp reconnaissance on the high seas and as an element in the atomic bomb. After the war, helium served as a key element in NASA's Cold War activities.

The center of helium research and production has been the U. S. Bureau of Mines' Amarillo Helium Plant, built in 1928-29. To support this plant's activities and meet growing military and private demands, Congress appropriated the necessary funds for the bureau to construct the Exell plant in 1942-43 to further the helium activity of the war and postwar periods. What follows is a history of helium and the role of these and other important plants during the twentieth century.

The History of Helium and the Amarillo Plant

Norman Lockyer discovered helium as early as 1868 as a new line in the sun's spectrum;

Lockyer, in fact, named helium from the Greek word for the sun, *hellos.* Not until 1895, however, did William Ramsey, a University of London scientist, discover helium in the earth's atmosphere. The United States government's interest in helium did not take off until 1917. By then, chemists had discovered its presence in natural gas fields at Petrolia, Texas, and Dexter, Kansas, but little had been done to separate it from the other gases as helium occurs only with other gases.

The exigencies of World War I accelerated the U. S. Air Corps' interest in acquiring pure, or nearly pure, helium for lighter-than-air ships. After preliminary discussions, the Navy funded the construction of a plant at Forth Worth, Texas, under the supervision of the Bureau of Mines. The plant began operations as early as March 1918, and was able to produce helium for the war effort by November, but the first shipment never left the seaport of New Orleans because the war ended and it was returned to Kansas. In 1920, the Navy, in cooperation with the Interior Department, established the nation's first cryogenic laboratory in Washington, D.C. for processing helium at extremely low temperatures. Because of the dangers of compression technology, however, by the mid 1920s the Secretary of Interior, Hubert Work, began searching for a safer place to process the helium away from the nation's capital and the basement of the Bureau of Budget.

In the meantime, Congress held hearings on helium in the early 1920s, culminating in the Helium Conservation Act of 1925. This act ensured the production and conservation of helium, under the supervision of the Bureau of Mines, and provided the appropriations that would carry the administrative program, known as Helium Activity, into the 1930s and beyond. As Clifford W. Seibel stated in his well-known book, Helium, Child of the Sun (1968), this act "authorized...the purchase, lease, or condemnation of land, conservation of helium gas, construction and operation of helium plants, [and] conducting [of] experimental work...of helium under certain conditions," namely for reasons of national defense.

After a preliminary investigation, the Navy, in cooperation with the Interior Department, decided to find a new location for helium production after scientists predicted the Fort Worth Plant's Petrolia field would run out of helium in the next few years. The investigators narrowed their choices for the new facility to the Nocona and Cliffside, Texas, fields with the latter proving to have the most advantages: 1) a large 50,000-acre site; 2) 700 pounds per square inch of pressure from the field; 3) twice the helium content (about 1.75%) of the Nocona field; 4) a virgin field; 5) 100 years supply at 1920s demands; 6) lease and royalty rights in fewer than six companies or individual's hands; 7) a reasonable price. With these advantages in mind, the Interior Department made the decision in 1926 to develop the Cliffside field and to construct a plant at Soncy, Texas (just west of Amarillo).

In 1926, the Bureau of Mines began negotiations for leasing and drilling rights to the Cliffside gas field with William H. Bush, entrepreneur, rancher, and developer in the Amarillo area, and the Amarillo Oil Company. By 1927, the bureau had secured rights to 20,000 acres of the Cliffside structure or Bush Dome. On May 16, 1929, the U. S. government attained rights to 50,000 acres. Simultaneously, the bureau acquired 18 ½ acres west of Amarillo at Soncy, a stop along the Rock Island Railroad. In return for the cost of drilling a water well ($746.76), Bush donated the site to the bureau. In July 1928, the bureau began construction of a 12-mile pipeline (a 6-inch line made of welded steel) from the Cliffside station, which by this time had four wells producing 30 million cubic feet of natural gas a day containing 1.75 percent helium, to the plant site. That same month, the bureau contracted with James T. Taylor & Company of Fort Worth to construct the new plant. Under the supervision of Clifford W. Seibel and his assistant George Erlandson, the Bureau of Mines began construction of the Amarillo Helium Plant in earnest in August 1928 (R.A. Cattell, head of the Petroleum & Natural Gas Division of the bureau supervised these men from Washington, D.C.). In the meantime, as operations were concluding at the Fort Worth Plant in January 1929, the Fort Worth equipment was being sent to the Amarillo plant.

The Amarillo Helium Plant site proved to have favorable access to transportation routes – Highway 66 and the Rock Island Rail Line – and water. In 1928-29, James T. Taylor & Company constructed nine major permanent buildings, which included the Administration Building (Building D), the Laboratory (Building C), the Garage (Building T), the Power House (Building R), the Separation Building (Building 06), the Instrument & Carpenter Shop (Building 03), the Machine and Welding Shops (Building P1 & P2), the Carbon Dioxide Removal Building (Building M7), and the Storage Warehouse (Building M8). In addition, the construction company built a Loading Dock (Building 01), a Storage Shed (Building 10), the Navy Building (Building N), three holding tanks (no longer present), an unnamed building just east of the Storage Shed that was removed sometime after 1956, and the High Pressure Storage facility (Building 9), which originally was used as a covered workshop area. Some of these buildings later were altered as expansion occurred in the 1940s and 1950s.

In addition to these important structures, the Bureau of Mines also constructed roadways in the plant; a water-cooling pond; water wells; a water tower; three gas holders; and water, steam, gas, electric, and sewage lines. A spur from the Rock Island Mainline also was built and extended to the Loading Dock. The pipeline construction crew also built a 10-inch pipeline off the 6-inch main from Cliffside to Amarillo to pipe residue gas that the city had purchased.

The Bureau of Mines equipped the plant with two carbon dioxide removal units designed in 1927 by the Cryogenics Laboratory in Washington, D.C., consisting of charcoal liquefaction units that could remove other gases to produce 97 percent to 98 percent helium. The plant had a production capacity, with two units in full operation, of 24 million cubic feet of helium per year. Initially, it cost the Amarillo plant about $23 per thousand to produce helium. Within four years, however, this figure dropped quite dramatically to $9.60 a thousand by 1933 (during 1932 this figure actually had been reduced to $7.10 a thousand). These costs are quite impressive considering the $2,500 per thousand cost of 1917.

Under the supervision of Seibel, the nation's Helium Activity went forward despite the economic interruption of the Great Depression. Early on in the plant's history, however, there was a small bump in the road when Congress held hearings in the 1930s to determine whether the government operation interfered with private commercial development of helium. Largely because of the protests of one private interest, the Helium Company, a Kentucky-based operation in Kansas, the hearings went forward. Representative Maurice H. Thatcher of Kentucky, in fact, who claimed that the government operation "crowded out of the picture this private enterprise," argued that the Amarillo plant should be operated for "national conservation . . . [and] as a matter of national defense . . . for emergency purposes, as well as experimental purposes, and at the same time to encourage private enterprise to produce helium. . ." This suggestion that the government was interfering with private enterprise did not sway Congress, however, especially because the economic conditions of the 1930s and the exceptional cost effectiveness of the Amarillo plant precluded the development of private helium production, at least until the 1960s. The same hearings revealed that the Amarillo plant, in its initial phase of 1929-30, produced helium and made it available to the Armed Services at $12 less per thousand than the Helium Company. Within three years, the government plant was producing helium at one-fifth the cost of the private company.

Even though Herbert Hoover, a longtime champion of private enterprise, was President, the government operation was not threatened by these pleas from the private sector. Even a person as renowned as Hoover for his support of private enterprise through government cooperation realized the significance of helium for national defense. During his time as Secretary of Commerce in the 1920s, Hoover not only supported wholeheartedly the Bureau of Mines Helium Activity (at the time the Bureau was in the Commerce Department), but also realized that the United States had a monopoly on helium, a strategic advantage that in the future might give the nation an important military edge. The idea that this strategic element could be available to the private sector, and therefore theoretically to foreign nations, was reason enough for the president and Congress to support continued operation of the Bureau of Mines plant.

Regardless of this early controversy, the Amarillo plant, with its production facility and research and cryogenics laboratories, led the world in helium production, development, and technology. The cryogenics process, for example, proved quite successful even though demands for helium were low during the 1930s economic crisis. After passing through charcoal and caustic filtering systems to remove carbon dioxide, the helium was sent through a cryogenic process that progressively reduced the temperatures in successive chambers. Because helium will not liquefy until a temperature of minus 452 degrees Fahrenheit, the nitrogen, oxygen, hydrogen, and other gases could be removed in liquid form, leaving the gaseous helium to be extracted and stored. During the 1930s, the Amarillo plant produced helium of approximately 98 percent purity, a high enough grade to be used for naval and army dirigibles that could be employed for reconnaissance of the high seas during naval operations.

The U. S. military, however, had a limited need for helium during the 1930s, largely due to a lack of demand for lighter-than-air craft during peacetime. Nonetheless, the U.S. Armed Services purchased the bulk of the 73,350,975 cubic feet of helium produced at the Amarillo plant from 1929 to 1936. The Navy and Army used most of this helium for their blimps; the U. S. Weather Bureau purchased some; and the National Geographic Society and the medical profession (through the U.S. Public Health Service), purchased a negligible amount of helium; the Goodyear- Zeppelin Corporation of Akron, Ohio, purchased a million cubic feet as early as 1935. Obviously, the foregoing figures do not even come close to the production capacity of 24,000,000 cubic feet per year. Economic factors along with airship disasters such as the loss of the *Akron* in 1933 reduced demand during the depression. The destruction of the *Akron,* in fact, not only reduced the Navy's need for helium, but it also directly affected employment at the Amarillo plant. Another tragedy, the loss of the *Macon* in February 1935, nearly forced the closing of the Amarillo plant. In fiscal year 1936 alone, forty-five employees were let go; as Seibel put it in his book, “there was a better-than-even chance that the plant would be closed permanently.” Clearly, peacetime conditions meant that the Navy was not inclined to replace the lost dirigibles and, therefore, would have a reduced need for helium.

Prior to fiscal year 1937, the highest single year of production occurred in fiscal year 1932 when nearly 17.5 million cubic feet of helium were produced, whereas the lowest single year during this time (after the initial opening year of 1929 when production commenced in April) was fiscal year 1936 at 4,663,355 cubic feet.

Prior to World War II, the focal point in the history of the Amarillo plant centered on a tragedy. As the war approached in the spring of 1937, and as private concerns became increasingly interested in acquiring helium, especially zeppelin companies in Europe that were using flammable hydrogen to lift their dirigibles, the drama began to unfold. Largely because of the inaccessibility to helium, due to its role in national defense, private parties -- including the Goodyear-Zeppelin Company, American Zeppelin Transport, Inc., the medical profession headed by Dr. Alvan L. Barach of the Columbia Medical Center, and German scientists and lighter-than-air craft company representatives – testified before the Committee on Military Affairs in 1937 in hopes of persuading Congress to make helium available commercially. Government restrictions that blocked sale to private parties and foreign nations, they argued, must be changed to make helium affordable for asthmatics and other patients as well as domestic and overseas zeppelin companies (especially because of the dangers of hydrogen-filled blimps).

The comments of T.A. Knowles, who represented American Zeppelin Transport, Inc., proved prophetic. Arguing that helium should be made available to domestic and foreign zeppelin companies, Knowles testified on April 22, 1937, that hydrogen was too dangerous for commercial zeppelin flights between Europe, South America, and the United States. And despite the outstanding safety record of the German companies, in particular, he warned, "flying in hydrogen-filled airships [was like] . . . riding on a stick of dynamite." He then predicted that a disaster was likely to occur involving the hydrogen-filled blimp, for if the "lifting gas [hydrogen] ignites, the passengers may be burned [to death] before they can get out."

Exactly two weeks later, the famous German airship, *Hindenburg,* burned in the sky above Lakehurst, New Jersey, on May 6, 1937, killing thirty-five passengers. "The tragic loss of the *Hindenburg,*" Seibel noted, "focused attention of the world on helium as perhaps nothing else could." Without a doubt, the publicity the Amarillo plant received after this disaster boosted the Bureau of Mines helium program. An article about the Amarillo plant that appeared in the May 9, 1937, issue of the *Amarillo Daily News* was released to eighty newspapers nationally. The Fox Movietone News picked up the story and ran reels showing the activities of the Amarillo plant in theaters throughout the country. In the end, the *Hindenburg* crash opened up new avenues for the governments helium operations; soon after, with passage of the Helium Act of 1937, Congress approved commercial purchase of the government's strategic element.

The Helium Act of 1937 authorized the Bureau of Mines not only to sell helium to private interests, but also authorized the purchase of the Girdler Corporation's plants in Dexter, Kansas, and Thatcher, Colorado. (The Helium Company was a former subsidiary of the Girdler Corporation.) These changes in policy, although still making it difficult for foreign interests to acquire helium (the president, and later the secretary of state, had to approve the sales), opened up new avenues for the struggling Amarillo plant and the Helium Activity, in general.

By 1940, with war raging in Europe, the Amarillo plant was selling a substantial amount of helium to the private sector. In fact, what had been an almost exclusively government-generated market prior to 1937 was opened up to a larger sector, although German orders for helium were blocked. In 1940 the government – the U.S. Armed Services and the U.S. Weather Bureau – purchased only 84 percent (7.9 million cubic feet) of the total production of 9,450,855 cubic feet, with the other 16 percent (1,514,155 cubic feet) going to private interests. The bulk of the private consumption (73 percent) went for medical purposes. A small amount also was sent to Poland for a stratospheric flight by the famed balloonist, Captain Antoni Janusz, who, ironically, was visiting the Amarillo plant in late 1939 when his visit was cut short because the Germans had invaded his homeland. The war ended Janusz's dream to fly the high altitude balloon.

The demands of World War II translated into a boom in helium production. As America's inevitable entry into the war edged closer and closer, President Franklin D. Roosevelt and Congress responded. The president approved the construction of 200 new lighter-than-air craft and in 1941-42 Congress appropriated more than $16 million for the construction of new helium plants and the expansion of the Amarillo facility. Helium production figures jumped from just more than nine million cubic feet in 1940 to 33 million cubic feet in 1942; 116 million in 1943; and 127 million in 1944. By the war's end, the Bureau of Mines had designed and constructed four new plants – Exell, Moore County, Texas; Otis, Kansas; Navajo, New Mexico; and Cunningham, Kansas – and expanded the Amarillo plant. Thus, the Helium Activity of the Bureau of Mines grew from one plant with 36 employees to four plants with more than 400 employees and from a production level of about nine million cubic feet of helium a year to nearly 140 million cubic feet a year. As the nation's top helium engineer, Clifford Seibel, put it: "With the handwriting on the wall, the helium operations of the Bureau of Mines, directed by 'Shorty' Cattell in Washington and by me in the field, went into high gear." Like so many other American industries during the war, the helium operations set monthly production records and assisted in defeating the most threatening aggressors in world history.

During the war, the Amarillo Helium Plant served as the Administrative Office of the entire governmental operation. This responsibility included surveying new gas fields for helium potential, experimenting in new technology, accounting, planning, and research. The bureau increased the Amarillo plant's production capacity by 50 percent in August 1942 when engineers put in a new separation unit. In addition to this expansion project, the bureau hired Stearns-Roger Manufacturing of Denver in 1942-43 to install an outdoor Carbon Dioxide Removal Unit, a Pump House (Building F), a Boiler Building (removed in 1971), High Pressure Helium Storage Tanks (in Building 9), an Engineering Building with women's showers and lockers (Building B), and Guard Towers (probably built during the wartime expansion). The construction company also extended and then enclosed the Loading Dock in 1943.

Helium played an important role in World War II. It was used in dirigibles that protected naval missions from submarines. Scientists at Los Alamos used it in the atomic bombs. Welders depended on helium to weld magnesium, aluminum, stainless steel, and a new metal – titanium – which was used in rocket construction. Meteorologists, whose forecasts often determined when a mission would go forward, depended on helium-filled balloons to predict weather. And finally, helium proved to be a life-giver in administering anesthetics and for soldiers suffering from respiratory disease.

Like many American industries, the Helium Activity experienced a rapid decline in demand during the postwar demobilization period. As a result, with the exception of Exell, each of the helium plants stopped production. In the postwar years, the Exell plant became the principal helium-producing facility in the world. It would not be until the 1950s that Helium Activity experienced revitalization and some expansion. In the meantime, the Amarillo plant remained the center of research. In 1946, the Bureau of Mines established the Helium Research and Utilization Program to refocus the Helium Activity program from wartime production to peacetime applications. In the end, the results ensured a continued demand for helium. At the same time, the bureau initiated an informal helium conservation program.

During the postwar period, chemists and engineers at the Amarillo plant focused strongly on helium research. Because demands for helium decreased with war's end, scientists had more time to spend on new and improved applications, leading to a dramatic increase in the commercial demand for helium, especially for use in welding. In fact, researchers developed shielded-arc welding techniques that provided exceptionally strong welds using metals such as titanium and zirconium, which were becoming increasingly important for rocket construction and would in the near future serve the space program. At the same time, because a purer helium was needed for this welding technique, the Amarillo and Exell plants developed and implemented new technology – such as the activated charcoal filtering system that removed greater amounts of nitrogen – to improve helium purity from 98.2 percent to 99.995 percent (referred to as "welding grade" or "Grade A"). Consequently, the commercial demand motivated governmental advancement in technology.

As a consequence of this new commercial demand, private consumption of helium produced by the Bureau of Mines increased dramatically. By 1948, for example, the commercial sector purchased 28 percent (18,868,867 cubic feet) of the total helium production of 67,486,567 cubic feet. This trend in consumption would continue into the 1950s.

The Bureau of Mines also initiated a helium conservation program in 1945. The Exell plant, which piped its processed helium to the Amarillo plant, pumped 20,629,400 cubic feet of helium (98 percent grade) into underground storage wells at Cliffside. This action not only initiated the government's helium conservation program, but it also elevated the Exell plant to the number one spot in helium production. At the same time that Exell became the principal helium producing facility, the Amarillo plant virtually stopped helium production in the late 1940s and served as a research center, as well as headquarters for the other plants, the principal shipping point for helium, and as the location for reconditioning cylinders used to transport and store the helium.

From 1947 through 1950, Exell produced virtually all the world's new supply of helium. During those four years, the plant produced nearly 270 million cubic feet of helium. The high of 81,394,416 cubic feet was produced in 1950; the low of 55,165,482 in 1949. By 1950, the Bureau of Mines had pumped more than 80 million cubic feet of helium into the Cliffside underground storage for conservation. Much of this supply would be pumped out, ironically, for use in the aerospace boom of the 1950s, which necessitated a more substantial conservation program beginning in 1962.

Another feature of the postwar demobilization period was the dismantling of the

Cunningham plant in Kansas. Largely due to a diminishing gas supply at the site, the bureau closed the plant in 1945. During the next three years, the bureau sent the equipment and materials from this plant to other locations, namely the Amarillo plant, which was becoming obsolete mainly because of age and its machinery, some of which had been imported from the bureau's first helium plant at Fort Worth. With these materials, the bureau constructed a new Laboratory (Building A), a new Loading Dock (Building H5), the Laboratory Annex (Building E), and a Cooling Tower. In addition, the Amarillo Powerhouse was modernized with the installation of a switchboard and three Ingersoll-Rand 300-horsepower units (two from Cunningham) which replaced four old 250-horsepower Bruce-McBeth gas engine generators.

The 1950s proved to be a watershed decade for the Helium Activity. Not only did federal demand skyrocket, mainly due to the "race to space," but by the end of the decade the government, for the first time, called for private development of helium. As early as 1951, the Bureau of Mines began to call for an expansion of its helium operations. Clearly, the Korean Conflict caused a renewed increase in demand for helium, which was a key component in the emerging military industrial complex. The Amarillo and Otis plants went back into production in 1951 and remained so until the proliferation of private producers in the 1960s. New annual production records were set each year during the decade. In 1951, the Bureau of Mines produced 112,009,200 cubic feet; in 1952, 144,556,100; in 1953, 161,086,800; in 1954, 190,741,400; in 1955, 220,710,600; in 1956, 243,879,700; in 1957, 291,457,300; in 1958, 334,175,000; and in 1959, 476,892,000. During the decade of the 1950s alone, production more than quadrupled; since 1940 it had increased forty-fold.

A clear indication of the growing demand was the decline in warehoused helium. Prior to 1952, the bureau, for future consumption, annually pumped millions of cubic feet of helium into the Cliffside storage facility, a deep underground former natural gas field sealed in dolomite. By the early 1950s, more than 87 million cubic feet of helium was in storage. Beginning in 1953, however, the government began to withdraw helium from the reserve to meet military, national defense, weather, medical, and industrial demands; less essential demands, such as gas for toy balloons, were not met. The annual withdrawal of helium from the Cliffside reserve reduced conservation numbers from 87 million cubic feet at the beginning of the decade to less than 17 million cubic feet in 1959. This latter amount would have equaled an entire year's production prior to World War II. But that was a drop in the bucket compared to the beginning of the 1960s, when annual production in government plants alone reaching 500 million cubic feet.

This situation raised concerns in the Bureau of Mines and the government in general. As early as 1953, the Budget Office of Defense Mobilization recommended an expansion of the Helium Activity of the Bureau of Mines, which stated in its *Annual Report* for 1953 that it was "reducing rather than augmenting its reserves for the future, which from the standpoint of conservation is not desirable . . . [and therefore] additional facilities" were needed. In February 1954, Stone & Webster Engineering Corporation, an outside firm hired by the Interior Department to evaluate the helium program, recommended the construction of a new plant or expansion of the current facilities. Congress responded later in the year with a $6 million appropriation for the expansion. At this juncture, the Bureau of Mines had to make a choice: build an altogether new facility at Keyes, Oklahoma, or expand the Exell plant. The decision was made to do both. The immediate solution, however, was to expand the Exell plant from its 60 million cubic feet a year capacity to 150 million cubic feet and to wait three years to complete the construction of a new plant at Keyes.

America's race to space clearly warranted the expansion project at Exell. When the Soviet Union launched *Sputnik* in 1957, the United States appeared to be trailing in space-age technology. Meeting the demands for our space program was a critical element of national preeminence during the Cold War, and the Helium Activity would be an integral part of that essential program. As a consequence, the bureau contracted with the Quaker Valley Construction Company in 1954 to complete Exell's modernization and expansion project. To assist in this expansion, the Amarillo plant also was expanded: the Laboratory (Building A) was extended to the south to include a new library and technical facility, and a Receiving and Shipping Dock (Building H7) was added. The plant remained the principal administrative, research, accounting, and shipping and receiving headquarters for the Helium Activity, whereas the Exell plant served as the foremost helium production facility in the world, often having an annual production in excess of its new, 150-million cubic-feet capacity.

While the Exell plant was being expanded, the Secretary of the Interior made the decision, with the cooperation of the Office of Defense Mobilization, to recommend that the National Security Council adopt a national helium conservation program. As a result, the Helium Policy Working Group was organized in August 1957, with an undersecretary of the Interior as chair of the group, which included members from the Atomic Energy Commission, the Bureau of the Budget, Office of Defense Mobilization, and the departments of Commerce, Defense, and Interior.

The Bureau of Mines not only was concerned with the helium withdrawals from the Cliffside reserve, but officials also realized that millions of cubic feet of helium were literally lost into the atmosphere when private companies burned or sold natural gas that contained helium. Once that helium entered the atmosphere, it was gone forever, wasted. The Bureau of Mines thought it was time to conserve that helium.

It should be noted that the Bureau of Mines surely was drawing from the experience of the minerals industry. As early as 1939, Congress passed the first stockpiling act, which appropriated funds to acquire copper and other minerals to store for future use. In 1946 and the early 1960s, Congress amended this act to ensure that America had ample copper and other strategic metals in case of a national emergency. The federal government, no doubt, began to view helium in these terms by the early 1950s.

Initially, the Bureau of Mines called for a 32.5 billion cubic feet conservation storage program, but the end of the decade was arguing for a 56 billion cubic feet program. Even after the expansion of Exell and the completion of the new plant at Keyes, Oklahoma, (Congress appropriated $12 million for this plant in 1958) the Bureau of Mines could not meet the growing helium demands, especially for space and atomic energy programs. If current needs could not be met, how could the federal helium program meet future needs? Something had to be done, resulting in the Helium Conservation Act Amendments of 1960.

From February to June 1960, Congress held hearings on the proposed Helium Act Amendments. The hearings made it clear that the availability of helium was imperative to the continued strength of the nation's space program. The 1960 presidential election, in fact, was predicated on the continuation of national defense, space, and atomic energy programs. Consequently, helium production played an important role in advancing these national defense programs. Scientists used the inert gas in maser (microwave amplification by stimulated emission) and laser (light amplification by stimulated emission of radiation) technology. Maser technology allowed telstar broadcasts from Europe and elsewhere in the world using only one billionth of a watt of power, while laser technology sent pencil-thin beams of light that could spot-weld detached retinas as well as transmit literally millions of telephone calls or television channels in a single-gas beam. Scientists also discovered uses for helium in superconductivity at extremely low temperatures. The uses of helium coincided with the incredible technological and scientific breakthroughs of the space age.

With the Helium Act Amendments of 1960, Congress responded positively to the Secretary of the Interior's call for helium conservation. This legislation gave "authority to the Department of Interior to carry out an effective, long-range program for the production, distribution, and storage of helium in order to assure a sustained supply, taking into account supplies from order sources, to meet essential Government needs."

The new law, passed in September 1960 and effective in March 1961, also encouraged private development of helium through government purchase by calling for the "possible construction of up to 12 new plants located on helium-bearing gas pipelines to extract the helium that would otherwise be wasted from the [natural] gas before this combustible gas goes to fuel markets." To meet this goal, Congress later appropriated $47.5 million a year (increased to $65 million in 1963) to the Department of the Interior to purchase crude helium (60 percent to 95 percent helium) from private producers even though, the act claimed, this "would not in the long run involve a subsidy from the Treasury." Dedicated in Amarillo on October 10, 1962, the helium conservation program was declared "a national program to conserve the limited and irreplaceable resources of helium gas -- dedicated to the public welfare in assuring maximum benefit from this unique and valuable element in the scientific and economic progress of the Nation and its people."

On the surface, the new conservation program appeared to be the solution for producing helium to meet the growing demands of the space age, as well as assuring the long-term continuation of the Bureau of Mines Helium Activity program. In 1960, in anticipation of the new federal demands, the Exell plant was expanded to a production capacity of 300 million cubic feet a year. (Six larger separation units replaced ten World War II units, and two more purification units were added.) In the end, however, this legislation encouraged too much expansion in helium production – eight new private plants were built by 1968 – and would serve as the beginning of the end of the Helium Activity of the Bureau of Mines.

As might be expected, the production of helium took a big leap forward during the 1960s. Helping at every turn was the nation's obsession with reaching the moon, as well as the material production needs of the Vietnam War, interest in nuclear energy, and a favorable economy. The trend that began in the early 1950s of achieving annual helium production records continued into the mid-1960s. Bureau of Mines production steadily increased from 1961, when 675 million cubic feet of helium were produced, to the 1966 peak of 784.5 million cubic feet. And even though the space program would climax with the July 1969 landing on the moon, the bureau's helium production rapidly declined after 1966, and by 1970 nearly all of the government plants, including the Amarillo plant, ceased production. Only the Keyes and Exell plants continued producing; by 1974 Exell temporarily discontinued production, as well. A clear indicator of this downward trend was the government's production of helium: 769 million cubic feet in 1967; 645 million cubic feet in 1970; 306 million cubic feet in 1973; 297 million cubic feet in 1976; and 269 million cubic feet in 1979.

What caused this dramatic downturn in helium production? The most obvious reason was the rapid decline in the federal government's demand for helium. NASA had achieved its monumental goal of landing on the moon. The Atomic Energy Commission had an ample supply for its activities. The Department of Defense gradually was demobilizing from Vietnam, and the United States and the Soviet Union were talking seriously about arms reductions. When added to a spiraling economy, the outcome was a rapid decline in federal demand for helium.

Further hampering government production of helium was a 1969 ruling by the U.S. Court of Appeals for the District of Columbia, which said that federal contractors no longer had to purchase their helium from the Bureau of Mines. As a consequence, contractors began purchasing helium from private sources. By 1968, eight private helium-producing companies operated in the Texas, Oklahoma, Kansas, and New Mexico gas fields. Among them were four that received generous twenty-two-year contracts from the Department of the Interior to sell their helium to the government for conservation. These government purchases were the core of the helium conservation program. While the bureau's plants – Amarillo, Exell, Keyes, Otis, and Navajo – were producing helium for the Air Force, NASA, the Atomic Energy Commission and other federal agencies during the 1960s, the private companies – Helex Company, Cities Service Helex, Inc., National Helium Company, and Phillips Petroleum – were selling millions of dollars of helium to the bureau for storage in the Cliffside field near Amarillo. By 1980, the private firms had profited in the hundreds of millions of dollars by selling nearly 40 billion cubic feet of helium, pumped through the government-built, 425-mile pipeline to the Department of the Interior for storage at Cliffside.

From 1963 to 1969, the helium conservation program seemed to be working quite well. As early as 1964, the Department of the Interior had purchased 2.6 billion cubic feet of crude helium from these private firms for $29.2 million. In the meantime, while privately produced helium was being stored at Cliffside, the Bureau of Mines plants easily met the federal demands. As federal demand for helium increased over the next three years, the Amarillo and Exell plants were modified to improve the purity of helium from "Grade A" (99.995 percent) to "High-Purity" (99.997 percent) by reducing the temperature of the charcoal purification units. The Bureau of Mines further improved Exell's performance in 1968-69, adding new instrumentation for remote monitoring and automatic control, and by replacing twelve small helium extraction units with one large unit to improve efficiency and production. On the surface, the Helium Activity program would have appeared to be gearing up for an increase in production to meet an insatiable federal demand. In July 1969, when the *Eagle* landed on the moon and Astronaut "Buzz" Aldrin vented his helium tanks, the government's helium scientists were elated despite the knowledge that their program was already in decline. It must have been a bittersweet moment for the nearly sixty scientists and almost 650 employees, some current and some former, of the Helium Activity to know the importance of helium to the space program. Helium also had served the nation well during the height of the Cold War. The Air Force's *Atlas* missile (and future rockets) needed helium pressurants to keep their tanks from collapsing in flight. The Atomic Energy Commission had used helium as a heat transfer medium to take heat from reactors' radioactive hot cores to produce the steam that drove the turbines and created electricity. Sealab II divers depended on helium for long-term underwater survival during their scientific investigations. The United States and the Soviet Union also joined in a cooperative venture, the so-called U-25B magnetohydrodynamics program, which required helium to produce electricity for the Moscow power grid. These and other scientific advances were achieved more easily because of that unique inert gas, helium. And now that President John F. Kennedy's goal of reaching the moon was a reality, the Helium Activity program was being reduced to a mere shadow of its former self.

At the lowest point, the Department of the Interior ordered the ceasing of production at the Amarillo plant on April 15, 1970. The *1970 Helium Division, Annual Report* declared 1970 "a year of adjustment, reduction, and major changes in plant facilities, operations, and personnel." This act marked the end of forty-one years of continuous helium production at the Amarillo plant. In addition, hundreds of Bureau of Mines employees lost their jobs (reduced from nearly 650 employees in 1965 to 289 by 1971). When the Undersecretary of the Interior attempted to terminate the private helium companies' twenty-two-year conservation contracts in 1971, to save the government hundreds of millions of dollars, the four firms filed suit and won a court injunction, forcing a continuation of Bureau of Mines helium purchases until the Helium Privatization Act of 1996. By 1978, the Department of the Interior owed the federal Treasury

$466 million for these conservation purchases.

Not all was lost for Exell, however. The rapid depletion of the gas fields at Keyes, Oklahoma, in the late 1970s and early 1980s meant a revival in production for the Exell plant. As a result, the Bureau of Mines in 1979, under contract with CTI-Cryogenics (a division of Helix Technology Corp.), installed a 600,000 cubic feet cryogenic purifier and a 500 liter-per-hour liquefier at the facility to gear up the plant for renewed production of helium. The bureau also had installed a helium liquefier at the Amarillo plant in 1978 for shipment of liquid helium from Exell production. Then, in 1980, Hudson Engineering Company installed a 1.0 MMCF Pressure Swing Adsorption (PSA) purifier at Exell. In 1986 the bureau installed new carbon dioxide removal and nitrogen-drying units, which used a molecular sieve as an absorbing media; the carbon dioxide removal unit thereafter allowed Exell to process crude helium directly from the conservation pipeline, resulting in the installation of a new intake (with scrubbers) from the Cliffside storage facility. Exell's lifespan was extended for at least another decade because of its proximity to the helium-rich natural gas fields of the Panhandle of Texas. By this time, federal demand had dropped to about 200 million cubic feet of helium per year, meaning that Exell's 500 million cubic feet capacity could meet that demand, however diminutive in relation to the past.

When the Keyes plant closed in 1981, the Exell plant produced 550 million cubic feet of high purity and 115 million cubic feet of liquid helium. Ironically, despite the limited federal demand for helium, the federal government's contractors and a growing worldwide demand for helium boosted the demand for the inert gas to more than a billion cubic feet a year. This spelled a dangerous trend for the Bureau of Mines helium operations because private companies, once completely dependent on the Department of the Interior's conservation program for a market, now had alternative markets outside the federal government. As a result, Exell's annual production hovered at about 350 million cubic feet during the 1980s when the world demand exceeded one billion cubic feet, and even reached two billion cubic feet by 1987. Ironically, it was in 1987 that the *Annual Helium Report of the Minerals Yearbook,* published by the Department of the Interior, announced: "Privatization of the Government's helium program, except the conservation storage operation [which still purchased privately produced helium], is currently under consideration."

By 1989, twelve private helium companies were in operation. This growth hardly pointed to a decline in national and international demand for helium. Rather it demonstrated a continued increase in the demand. The technological applications of helium continued to increase during the 1980s and 1990s. NASA, for example, used helium in the space shuttle *Challenger* and in the *Columbia* orbiter; NASA also used helium-filled blimps to detect ozone depletion in the atmosphere over Antarctica. Scientists depended on super-cooled liquid helium for the Superconducting Super Collider. And the medical world continued to find new ways to enhance medical technology, using helium in state-of-the-art equipment such as Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imagery (MRI) to replace exploratory surgery to diagnose illness in patients. The Department of Defense even employed blimps to stifle drug trafficking along the nation's southern borders.

As part of the Clinton administration's and Congress' plans to reduce the federal deficit, the helium program came under heavy scrutiny in the 1990s. The result was the Helium Privatization Act of 1996. Justification for this act included a huge debt built up by the federal helium program that totaled nearly $500 million, while at the same time the private helium industry was expanding to eighteen plants owned by fourteen companies. In the end, the act called for: 1) ceasing of Bureau of Mines helium production and giving federal contracts for helium to private industry; 2) disposal of all facilities, equipment, and other real and personal property, and all interests therein, held by the United States for the purpose of producing, refining and marketing refined helium; 3) selling of the stockpile of crude helium from the Cliffside storage in an orderly manner; 4) continuing the operation of the Cliffside storage system, which included use of the storage fields and pipeline system, for storage and distribution of government-owned and privately owned crude helium; 5) continuing of federal land lease helium extraction contracts; and 6) payment of all moneys received by the sale or disposition of helium on federal lands to the U. S. Treasury to be credited against the amounts required to be repaid to the Treasury.

The act then transferred all right, title, and interest of the United States in 331 acres of land in Potter County to be donated to the Texas Plains Girl Scout Council. In addition, the act ordered the Secretary of the Interior to "enter into appropriate arrangements with the National Academy of Sciences to study and report on whether such disposal of helium reserves will have a substantial adverse effect on United States scientific, technical, biomedical or national security interests." And finally, the Secretary of the Interior also was to determine the impact of the selling of the crude helium reserves on science, technology, biomedicine, and national security. If the Secretary were to find an adverse effect, he was to make recommendations for proposed legislation "as may be necessary to avoid such adverse effects."

With this act, Congress ended eighty years of government production of helium.

Currently, the Department of the Interior is in the process of shutting down its own operations, an industrial achievement that evolved from a kernel of an idea during the First World War to an incredibly advanced technological industry in the 1990s. Ironically, it was the hard work and genius of government-trained and government-employed chemists, engineers, technicians, and general laborers who advanced the helium industry from a somewhat primitive technological program that produced 97 percent helium in the 1920s to a sophisticated international industry that produced 99.999999 percent and higher grade helium for the world's most advanced aerospace, energy, and medical technologies. In the end, this Cooperative State program that took off during Herbert Hoover's era is now coming to a close with the real benefits going to private companies who were able to cull the vast knowledge of helium extraction, processing, and production from the U. S. Bureau of Mines and its experts who sustained the industry for most of the twentieth century.

The History of Technology, 1917-1970

The history of helium processing technology is linked inextricably to the activities of the U.S. Bureau of Mines' Amarillo plant. Engineers, chemists, machinists, and other experts collectively worked throughout the twentieth century to design the cryogenic processes that resulted in the separation of helium from other elements such as oxygen, hydrogen, nitrogen, and later neon. The Amarillo plant, in particular, served as the focal point for the evolving technology, as well as emerging uses of the inert gas. Engineers devised the evolving cryogenic technology and researched new methods to produce an increasingly purer product to meet the growing demands for helium, first during World War I, then during World War II.

The bureau's Helium Activity continued to set the standards for helium production technology in the Cold War period to meet the escalating needs of the military industrial complex. The unprecedented demands for helium during the Cold War inspired still more efficient technology to provide the nuclear and aerospace industries with a purer product. And like other strategic minerals, helium was targeted by Congress with the Helium Conservation Act of 1960 for stockpiling to consolidate the United States' monopoly of the special gas. The Bureau of Mines' successful development of helium technology, combined with the conservation program, paved the way for privatization of the industry, facilitating private industry's ability to meet growing international demands for gaseous as well as liquid helium during the space race. In the final analysis, the Helium Privatization Act of 1996 spelled the end for the government program, which had provided the technology and research for the private takeover of the industry.

The following narrative examines the evolution of technology and research at the Amarillo facility from 1928 until the 1970s, and at the Exell facility from its construction during World War II to the 1990s.

Early Helium Technology & Demands, 1917-1941

The United States began producing helium in 1917 to provide lifting gas for the Allies' World War I dirigibles. Secrecy surrounded the joint effort of the U.S. Bureau of Mines and the U.S. Navy to develop the cryogenic technology needed to separate helium from natural gas. In the interest of national defense, the United States used the code name "X" gas for helium, while the

British called it “C” gas. Because no other nation or private interest had yet developed the technology to process helium, American engineers and chemists were treading on new scientific ground. In the meantime, the bureau conducted an extensive survey of natural gas wells in Texas, Kansas, New Mexico, Colorado, Utah, Wyoming and elsewhere to determine the availability of helium. The sample gases were then tested to determine the percentages of helium, which ranged from an unusually high 7 percent and above at the Rattlesnake Field in New Mexico to just under 2 percent in the gas from the Cliffside Field, which became the main source of government-produced helium. The potential for a U.S. monopoly on helium proved to be a seductive justification for federal establishment of this national defense industry as early as 1917.

That year, Congress appropriated $500,000 for the Navy to establish three experimental helium-processing plants in cooperation with the Bureau of Mines. After evaluating three extraction techniques – the Norton, Air Reduction, and Linde processes – at experimental plants in Fort Worth, Texas, from 1917 to 1919, the government constructed a Linde process helium plant in Fort Worth near the Petrolia Gas Field. In the meantime, the Bureau of Mines established the Cryogenic Research Laboratory in Washington, D.C., to investigate low-temperature helium processing techniques. Bureau scientists William M. Deaton, Clifford W. Seibel, F.G. Cottell, and others experimented with charcoal purification in their cryogenic research, but decided not to use this absorption technique, though, ironically, the process became essential during World War II and later.

The efforts of the helium program during World War I proved successful even though the only shipment made during the war never left the port of New Orleans and was later returned to

Fort Worth. The U.S. monopoly, however, would propel the program to new heights despite its near demise after the Navy's two remaining dirigibles, the *Akron* (1933) and the *Macon* (1935), crashed in the Great Depression years, threatening to eliminate the need for helium.

The first sign of a long-term federal helium program came with the Helium Conservation Act of 1925, which established the Bureau of Mines as the parent agency of the program and established guidelines for meeting the Navy's demands for the non-flammable gas. Likewise, the act determined that the government program should provide helium at a reasonable cost for medical purposes, especially for treatment of asthmatics, as well as other non-governmental demands.

In 1926, after forecasting the exhaustion of helium-bearing natural gas from the Petrolia field, the Bureau of Mines decided to move its principal operations from Fort Worth to Amarillo, in the Texas Panhandle, where the Cliffside field, discovered in 1921, was thought be more suitable to a long-term program. The operations moved under the leadership of R.A. "Shorty" Cattell, head of the helium program in Washington, D.C. At Amarillo, Clifford W. Seibel served as supervising engineer of the Helium Activity, which now had at its disposal the 50,000-acre Cliffside field and an eighteen-acre plant site at Soncy, a few miles west of Amarillo. After overcoming several obstacles, the helium program launched its cryogenic processing and research operations in April 1929. In the meantime, the bureau dismantled the cryogenics laboratory in Washington, D.C., and reassembled it at the plant in Amarillo. By 1929, all helium production and research operations were in one location.

Helium Production Technology at Amarillo prior to World War II

The U.S. Bureau of Mines constructed the Amarillo plant based on previous research and development at the Fort Worth plant and the Cryogenics Laboratory in Washington, D.C. Initially, the bureau put into operation several important pieces of equipment, including two separation units with about a 24 million cubic feet (mmcf) annual production capacity, to process helium through low- temperature processes. Seibel and his operations and research teams designed the plant to remove unnecessary gases from the natural gas feed from methane to oxygen to nitrogen to produce 98.2 percent pure helium.

First, the process required removal of carbon dioxide (CO_2) that made up about 0.7 percent of the intake gas in the CO_2 removal units. Carbon dioxide, if not removed, solidified during the super cooling process and plugged the apparatus at less than 600 pounds of pressure per square inch (psi), so the feed gas was scrubbed with a 7 percent "solution of caustic soda in the extended system of steel tubing." Water vapor and some hydrocarbons accumulated in this process, but they were removed in the first section of the heat interchangers, also known as heat exchangers, where the gas was then fed.

The remaining gas was sent through the cryogenic process to liquefy all of the gases except helium (and traces of nitrogen and neon) to reach 98.2 percent purity. Helium will not liquefy until about minus 452° F, only seven degrees above absolute zero at about minus 459° F. Nitrogen liquefies at about minus 312° F; however, at this early juncture some traces of nitrogen remained in the helium processing technology. Before liquefying the nitrogen, the raw gas entering the plant was run countercurrent and then cooled by residual gas leaving the system after the helium had been removed. Hydrocarbons and most of the nitrogen were removed in this process of liquefaction. These residue gases then returned to the heat interchangers and were vaporized at room temperature, and then passed out of the plant as residue gas, which was sent by pipeline to Amarillo for use as fuel at the local zinc smelter. At this stage, the remaining helium-nitrogen mixture (with traces of neon) was "crude helium," or a gas mixture that contained about 50 percent helium. The nitrogen from the initial liquefying process went to the nitrogen interchangers to be used in the cryogenic helium purifying process. Eventually, the Amarillo plant produced enough nitrogen, separated in this process, for the super cooling phase of helium purification.

After the first cooling stage, the crude helium was compressed and then sent through a second series of heat exchangers. The crude helium then went to the purifier, or a container, which was surrounded by liquid nitrogen, "liquefied by the aid of expander engines in an auxiliary system." In this purification process container, the temperature dropped to approximately minus 312° F under about 2,500 psi. At this temperature, "placing an icicle in the ultra-cold liquefied gases … would be like thrusting a hot poker into tap water." Virtually all of the remaining nitrogen in the crude helium was liquefied and siphoned off, some of which was recovered to be used again to super cool the incoming crude helium. At about 98 percent purity, the processed helium was the highest grade of helium produced in quantity prior to World War II. It was then warmed to atmospheric temperature through interchangers and sent to railroad tank cars and small steel cylinders for transportation.

Andrew Stewart, author of *About Helium* (1933), explained that "each cubic foot of natural gas comes to the plant at ordinary temperature and under a pressure of about 600 pounds per square inch; it passes through the plant at express-train speed, is dropped in temperature to about 250° below 0° F, and is again raised to ordinary temperature, all in the sensationally small space of less than a minute of time. It leaves the plant at about 75 pounds pressure." In essence, what might seem to be a very complex, long-drawn-out process took less than sixty seconds to complete to produce one of the world's most unique gases, helium.

Transportation of Helium

The Bureau of Mines transported helium in two types of containers, both freighted to their destinations by rail. First, the bureau used Navy and Army tank cars, consisting of "three or more large, heavy-walled seamless steel cylinders mounted on railroad trucks." In the 1930s, the Navy had "several" of these cars, and the Army owned two. These tank cars were built specifically for helium transport at 2,000 to 2,500 psi and with 200,000 to 215,000 cubic feet capacity under normal atmospheric conditions. Second, the bureau used the small cylinder, normally shipped in railroad boxcars. With a capacity of about 1.5 cubic feet under 1,800 psi, the cylinders were the standard used in transporting the more common gases, hydrogen and oxygen. The released helium from these cylinders under normal atmospheric conditions produced about 178 cubic feet of helium. The bureau preferred tank-car freighting because one tank car could transport the same amount of helium as that held in between eleven and twelve hundred cylinders, which required two freight cars. The bureau sent the bulk of its helium, which did not exceed 18 mmcf production in a single year prior to 1937, to naval air stations and army air corps installations.

To store the purified helium, the bureau had constructed a specially designed high-pressure storage facility at the Amarillo plant. Engineers removed the valves from 24,000 small cylinders and then connected them together with a manifold system of tubing. This makeshift system stored about 3.5 mmcf of helium under approximately 1,500 psi. Able to store almost two months total capacity, this storage facility seemed enormous at the time, but would meet less than a tenth of the demand as early as the World War II years.

Cryogenic Research and Gas Analysis at Amarillo

The Cryogenic Laboratory at Amarillo served two principal functions: to improve processing techniques in the production of helium and to test natural gas samples taken from all over the United States to determine the percentage of helium and the possibilities for its production. Less urgent, a third function of the laboratory was to conduct research designed to discover new use for the odorless, tasteless, inert gas. As Stewart observed: "When helium production was initiated [in 1917], the data then existing in this field were scanty, and it early became apparent, as the Government helium project developed, that a laboratory devoted to research along these lines [of scientific and engineering problems] was absolutely essential to succeed. The U.S. Bureau of Mines cryogenic research laboratory was therefore established."

The national and even international significance of the bureau's Helium Activity was apparent when renowned Polish-French physicist Madame Marie Curie took time from her schedule while visiting the United States in 1921 to dedicate and open the government's first cryogenic laboratory in Washington, D.C. The bureau moved the laboratory to Amarillo in the late 1920s because of proximity to the Cliffside gas field and the fear that the Washington laboratory would compromise the safety of workers in the Bureau of the Budget, which was situated in the same building as the cryogenic facility. Under the supervision of William M. Deaton, laboratory staff analyzed the effectiveness of the production plant, tested and analyzed natural gas samples, and conducted numerous other research projects related to specific heats, phase equilibria, solubility of helium in the liquid components of natural gas, behavior of metals at low temperatures, heat exchange, insulating materials, removal of CO_2 from natural gas, and methods of obtaining the necessary refrigeration. Laboratory engineers and chemists also experimented with railroad charcoal-purification cars, providing the data and experience necessary for the bureau to construct a small purification plant at the Naval Air Station in Lakehurst, New Jersey, and two other units, one a permanent structure, the other a mobile unit, at the Army Air Station at Scott Field in Belleville, Illinois.

Perhaps the most actively used piece of equipment in the cryogenic laboratory was an apparatus used for separating and measuring helium samples. Concerned with the limited sources of helium, the bureau conducted an exhaustive survey of natural gas samples from not only the helium-rich fields of Texas, Kansas, New Mexico, and Colorado, but from all over the American West, elsewhere in the United States, in Canada, and from other "free" nations. In general, however, the bureau was little inclined to share production secrets with the rest of the world, especially as the impending Second World War approached in the late 1930s. The small apparatus described below was an exception to this rule.

Unlike the helium production facility at Amarillo, the apparatus for separating and measuring helium samples used activated coconut charcoal to adsorb alien gases. The apparatus cooled the gas sample to liquid-air temperatures, allowing for the adsorption of nitrogen and other constituents of the gas. When processed in this apparatus, the helium attained a "spectroscopically pure state." Designed by personnel of the bureau's Cryogenic Laboratory, this helium apparatus replaced the more laborious chemical method earlier used to test natural gas samples for helium content.

Instead of the three-step process (burning hydrocarbons, adsorption of CO_2 in caustic solutions, elimination of oxygen with alkaline pyrogallate solution, and removal of nitrogen through sparking or by mixing it with hot calcium or magnesium) the apparatus, which in some ways was even more efficient than the production plant itself, used a physical rather than chemical method to separate helium from the natural gas and its constituents. To adsorb nitrogen, methane, carbon dioxide, oxygen, and other gases, the natural gas samples passed through the apparatus and the activated coconut charcoal tubes, cooled to liquid-air temperatures. The pure helium (with traces of nitrogen and neon) was then measured for percentage in the burette. To ensure that the gas passed through the apparatus at an effective pressure per square inch, the apparatus also was equipped with a Töpler mercury pump for accuracy. The bureau, however, had not yet discovered how to effectively use the activated coconut charcoal adsorption method on a large scale in the Amarillo production plant. Not until federal defense contractors needed a higher purity of helium (99.995 percent) for heliarc welding of titanium, zirconium, and aluminum used in aerospace technology would the bureau implement the activated charcoal system at Exell and other new plants during and after World War II.

Principal Uses of Helium Prior to World War II

The federal government established the helium program specifically for national defense purposes. Consequently, the Navy and Army used more than 90 percent of the annual production for dirigibles such as the *Shenandoah,* the *Akron,* and the *Macon* prior to 1941. Another 5 percent to 7 percent of the helium went to nongovernmental uses such as caisson work for underwater divers, breathing apparatuses for asthmatics, and toy balloons. A small percentage also went to the U.S. Weather Service for that agency's weather balloons. Additional uses for helium were forecast in the early 1930s: preservation of food, research on refrigeration processes, cooling for electric motors, fireproofing of high-tension switch boxes, and a wide range of scientific applications.

Research on superconductivity was among the more intriguing investigations of the Cryogenic Laboratory and in private industry. Scientists discovered that mercury became a superconductor of electricity when cooled by liquid helium. Eventually, chemists and engineers at the Amarillo laboratory and in private industry would discover many more applications for helium, including its use in the nuclear and aerospace industries.

Helium Activity and World War II

When the Navy's only surviving dirigible, the *Macon*, fell into the Pacific Ocean on February 12, 1935, officials of the helium program feared the worst. Government demands for helium plummeted, production at the Amarillo plant nearly ceased, and most of the plant's employees were let go; Seibel even took on janitorial duties. In the midst of the downturn, however, two orders -- one from the Goodyear Company for advertising blimps and one from the National Geographic Society for the flight of the *Explorer II – a* stratospheric balloon flown from the Black Hills to White Lake, South Dakota in 1935 – saved the program through 1936.

Like so many private businesses, the government-operated helium industry faced its own demise during the 1930s. This outcome, however, did not materialize in large part because of one event, the fiery crash of the German airship, *Hindenburg*, on May 6, 1937. The hydrogen-filled balloon burst into flames at the very moment that the House Committee on Military Affairs was hearing testimony from commercial interests such as the American Zeppelin Company and the Luftschiflbau Zeppelin company of Germany, calling to make the monopolized gas available for private use in airships (hydrogen, of course, was flammable). C.W. Seibel, longtime head of the Amarillo operations, later recalled that "the tragic loss of the *Hindenburg* focused attention of the world on helium as perhaps nothing else could." The end result was congressional passage of the Helium Act of 1937, which made helium commercially available at market value for medical purposes.

For the first time, non-Americans also could apply for helium export licenses that, for national security reasons, required approval by the secretaries of state and interior. With the promise of larger domestic and international markets for their helium, bureau officials forecast a brighter future. Events in Europe beginning in 1938, however, delayed peacetime expansion of the helium program. On the other hand, the rapid emergence of the American military industrial complex in the 1940s ensured new demands for helium that would continue to escalate during the Cold War era.

Like uranium in the postwar years, helium was perceived as a strategic mineral during World War II, when its demand skyrocketed. As early as 1939, the Roosevelt Administration called for 48 new dirigibles. At the height of the war, the Air Corps' fleet of lighter-than-air craft served as the principal aerial reconnaissance, including during the Normandy invasion and other high seas engagements.

By the time of U.S. entry into the war, military demands for helium were increasing to unprecedented levels. The Navy alone anticipated a 50 mmcf per year demand, more than double the capacity of the government's only plant at Amarillo. In 1940, Seibel anticipated this new demand, warning his colleague "Shorty" Cattell in Washington, D.C., in an October letter. The chief chemist of the helium program lamented that the Amarillo plant, then eleven years old, needed repairs and upgrading. Not realizing there would be a forthcoming boom in helium demand, Seibel incorrectly believed that the Weather Service would be the largest consumer of helium. In fact, the greatest demand, even before the war ended, was for welding. Welders used helium to produce an atmospheric shield to exclude oxygen and nitrogen when welding magnesium and other metals (later important for welding titanium and zirconium used in rocket science and for welding aluminum) to prevent ignition of the metals or formation of oxides and nitrides that reduced the strength of the welds. Defense manufacturers used helium shielded welding "extensively in the fabrication of bombers and fighter planes."

As U. S. involvement in World War II seemed imminent, Congress responded in August 1941 with a $1.25 million appropriation for construction of a new plant. That plant would be Exell, initiating the wartime expansion of the Helium Activity from a single plant at Amarillo to five: Amarillo, Exell, Otis, Navajo, and Cunningham. Before the end of the war, the bureau, which designed and fabricated most of the plant, used a $4 million appropriation to expand Exell from its original four separation units to ten units. The bureau also expanded the Amarillo plant with an additional separation unit, a new carbon dioxide removal unit, and a 600-horsepower, three-stage compressor to supply nitrogen for the refrigeration cycle. As a result of the expansion program, helium production soared from a pre-war level of 6.2 mmcf in 1939 to 137 mmcf in 1944.

Helium technology did not change during World War II. With some minor modifications, the expansion project implemented the available technology used at the Amarillo plant. The bureau, for example, constructed the Exell plant, its separation units, compressors, and engines on a larger scale to increase production capacity and to make adjustments to lower levels of helium (approximately 1 percent) in the Channing field gas, which was the supply for Exell. The 98.2 percent purity level of helium produced by the bureau met standards for dirigibles and for the welding of magnesium and other metals used during the war.

Consequently, the bureau's helium program was up to the wartime challenge. Once the war was over and the aerospace industry took off in the late 1940s, and especially in the 1950s, a higher grade helium (99.995 percent or better) was needed for a newer welding technique called heliarc welding, which defense contractors utilized extensively to weld titanium, zirconium, and aluminum.

Helium Technology and the Cold War, 1945-1970

The traditional demand for helium was as lifting gas for the nation's military airships; but with the end of World War II, there was little need for the high-flying blimps. The unprecedented leaps in air and aerospace technology hardly warranted the use of the vulnerable dirigibles. The immediate drop in helium demand forced the bureau temporarily to cease production at all of its plants except Exell. Seibel and his research team, fearful of the demise of the government-operated industry, sought new uses for helium, still anticipating that the Weather Service would be the principal consumer of the gas. As early as February 1944, H.S. Kennedy, assistant director of the U.S. Bureau of Mines, foresaw the postwar decline in helium demand, leading him to write to Seibel: "I think it well for everybody to be working on new uses for helium and especially uses that will aid in the prosecution of the war." Even before the war ended, helium program officials began contacting potential users, such as the Ford Motor Company, Lockheed Air, and numerous governmental agencies, among them the Manhattan Engineering Project in Hanford, Washington. During the fall of 1945, Seibel made an extensive road trip from Amarillo to Chicago, Cleveland, New York City, and Washington, D.C., contacting private companies and government agencies in hopes of expanding the helium market. He became so confident that helium demands would recover from the postwar decline that he bragged in his report that Walter Bender of the Ohio Chemical Gas Plant in Cleveland said of Helium Activity that "at least one branch of the Government had demonstrated they could do business as a commercial outfit did." In their search, Seibel and his cohorts discovered that new demands were emerging for helium, initially in nuclear energy and then in the aerospace industry.

The catch was that a higher grade helium was needed. No longer would the 98.2 percent grade meet the requirements of the principal use in the Cold War period -- shielded arc welding. Consequently, researchers and plant operators began to search for a way to produce a higher grade helium, perhaps as high as 100 percent purity. In response, chemists and engineers investigated the use of activated coconut charcoal, which already was in use on an experimental level, and for separating and measuring helium in natural gas samples at the Amarillo and Exell plants. If successful, the helium program could meet the growing needs of the military industrial complex and assure the continuation of the United States' monopoly of the helium industry. During the Cold War, civil and military leaders agreed that any advantage the nation's atomic, nuclear, and aerospace industries could gain over the Soviet Union would aid in the collective fight to contain communism. Helium and its uses were closely linked to American Cold War aims.

Charcoal Purification Technology

In August 1949, the Bureau of Mines announced that a new, purer grade of helium would soon be available for use. Helium program officials called it "Grade A," a helium that was oil and moisture free, "approximately 100% pure," to be transported in oil-free containers. To achieve this new grade of helium, the bureau had perfected the use of activated coconut charcoal in the adsorption process (discussed below), and in this case the nearly pure helium was "double charcoal purified." The bureau had met the criteria for a purer helium product for the Atomic Energy Commission and for the aerospace industry. Defense industry leaders viewed this technological breakthrough as very significant because it gave the United States an advantage in welding the bodies of rockets and in detecting fuel leaks in those rockets. It could not have come at a better time because the Soviets detonated their first atomic device that same year of 1949. The availability of 99.995 percent and purer helium gave the Americans a distinct advantage in producing their nuclear arsenal during the unprecedented nuclear arms race of the 1950s and 1960s.

Grade A helium also would be available for inert gas protection for molten metal, as a refrigerant in low-temperature cryostats, and for "special scientific work." In addition, the bureau announced that three other grades of helium would be available as well. These included 99.8 percent pure Grade B helium or single "charcoal purified" (versus double charcoal purified), which was moisture and oil free, for use in pressurizing liquid propellants (fuels) in jet propulsion and in optical instruments. Grade C helium, which was the highest grade prior to charcoal purification, served as a "breathing helium" and did contain some moisture. The final, Grade D helium, which was oil-contaminated, contained some moisture, and had a purity of about 97.5 percent, would be available for airships and balloons.

Bureau chemists and engineers knew of the efficacy of activated coconut charcoal for purifying helium as early as the 1920s because it had been used in the special apparatus used for separating and measuring helium in natural gas samples and in railroad charcoal-purification cars. In the 1920s, however, helium program officials abandoned the idea of using the charcoal process on a large scale in the Fort Worth and Amarillo plants because there was no demand for a higher grade helium and the charcoal process was more expensive and technically complicated. With the emerging demands for a purer helium product in the immediate postwar period, however, the bureau began to reinvestigate the possibilities of charcoal purification for large-scale production.

As early as January 1946, the bureau began experimenting with charcoal purification at the Exell plant. Over the course of the next two years, chemists and engineers improved the technique, then implemented changes in production at Amarillo and Exell by early 1948. In the meantime, bureau experts examined previous charcoal techniques, including one devised by the DuPont Company, and concluded that even though a higher grade helium resulted (e.g., with 6 percent greater lifting power), finding the right combination of gas pressure, amount of charcoal, and adsorption rate had to be ironed out before the process proved cost-effective, efficient in eliminating nitrogen and other contaminant gases, and technologically sound. At one point, Amarillo officials even considered abandoning charcoal processing in favor of purification over heated copper oxide.

In February 1946, bureau scientists began using "charcoal pots," or copper tubing 4 inches in diameter and 11 feet long, within the cryogenic cycle used since the early 1920s. At this early juncture, the investigators discovered that one of these pots could purify about 6,000 cubic feet of helium at from 99.5 percent to 99.9 percent purity. Even though the bureau began storing this new grade helium in cylinders, they had not yet figured out how much charcoal would be needed and how often it would need to be changed to maintain a high level of purity. Despite these obstacles, Amarillo officials already were planning to implement the technique at Exell, saying: "We are now attempting to find high pressure tubing to make enough charcoal pots to purify the entire production at Exell."

Over the next two years, the bureau evaluated and experimented with charcoal purification.

During this investigative phase, government scientists worked with other federal agencies as well as the Canadian National Research Council to determine the effectiveness of the technique. Amarillo officials were so confident of the future demand for the purer helium that they requested a supplemental appropriation of nearly $90,000 for a new research facility to conduct research on charcoal purification and potential uses for a purer product.

The final step toward producing Grade A helium came in March 1949, thirteen months after charcoal purification had been installed at the Amarillo plant. Just weeks before the bureau announced to its consumers that the purer product would be available, engineers discovered that about 1 percent hydrogen still remained in the processed helium. The hydrogen content was particularly problematic for welders, who noted that their welds were far too porous. Eventually, engineers discovered the right combination of charcoal and pressure to adsorb the troublesome hydrogen.

By May 1948, engineers had installed charcoal purifiers at the Amarillo and Exell plants. Since Exell had become the principal producer and would remain so in the government program until the 1990s, the Exell plant became the focal point for all future technological innovations, beginning with charcoal purification. Each of the charcoal purifiers at Exell consisted of three

> vessels containing charcoal arranged so that 2 of the vessels may be operated in series while the third vessel is being regenerated [new charcoal or cleaned charcoal]. Each vessel was fabricated from 7-5/8" O.D. Monel tubing and contains about 2.5 cubic feet of charcoal. The charcoal now in use was purchased from Barneby-Cheney Engineering Co., Columbus, Ohio. The temperature of 98.2% pure helium entering the first vessel in

the series is 175°-180° below 0° C. No external refrigeration is provided. Regeneration is accomplished by heating the charcoal bed with hot nitrogen to a temperature of about 50° below 0° C and then evacuating the vessel to 5-7 mm. Hg pressure. Experience has shown that each vessel of charcoal will purify 10,000-12,000 cubic feet of 98.2% pure helium measured at 14.7 psi absolute pressure and 70° F. to a purity of 99.5% or better, the impurity being hydrogen and only a trace of nitrogen [as well as neon]. In other words, each cubic foot of charcoal adsorbs 50-60 cubic feet of nitrogen.

The charcoal purifiers were placed at the end of the cryogenic cycle as the final phase in the upgraded process. The charcoal purification technique worked well at the Amarillo and Exell plants and prepared the Helium Activity for the helium boom during the nuclear arms and space races in the 1950s and 1960s.

Brief mention also should be made concerning the apparatus for separating and measuring natural gas samples (discussed above). This piece of equipment had been invaluable for determining which gas fields were the richest in helium. However, the apparatus, which did use charcoal purification, had become cumbersome and tedious. Consequently, Amarillo chemists continued to experiment with it to find a more efficient means of measuring the helium (the separation technique with charcoal was sufficient). They discovered that instead of measuring the helium with a burette, which took about forty minutes to complete, they began "measuring the pressures created by . . . pure helium when it . . . [was] expanded into a constant calibrated volume." The "sensitive pressure-measuring device" was connected to the charcoal tube, which gave two pressure readings and the volume of the original sample allowing the chemists to calculate the purity of the helium. This would save scientists both time and money, for it took less than ten minutes to test the natural gas samples, whereas the burette measuring technique took about forty minutes. Because this device was portable, it also could be taken into the field, saving even more time.

The Helium Boom and the Race to Space, 1950-1970

Little would change in helium technology in the three decades after implementation of the charcoal purification process. The higher grade purity met cold war demands. The issue the bureau faced beginning in the 1950s was how to meet the skyrocketing demands of the military industrial complex. By 1951, the bureau began to realize that its production capacity could not meet the defense industry demands for helium, especially for heliarc welding. Indicative of this deficiency was the bureau's decision to begin extracting stored crude helium from the Cliffside field. Since 1945, the bureau had been pumping crude helium into underground wells as part of the nation's larger mineral stockpiling program. Copper and uranium, for instance, also were stockpiled in case of a national emergency. In the case of helium, the bureau had stored about 88 mmcf of the vital element through 1952 even though there was no specific helium conservation program mandated by Congress.

In 1952, in fact, R. A. Cattell and others in the Bureau of Mines began calling for expansion of the government's helium program. The editors of *Chemical Week* projected that "expanding governmental and civilian uses for helium are building a mighty attractive and perhaps soon-to-be-tight market." This prediction came true soon thereafter. Throughout 1954, 1955, and 1956, helium consumers felt the pinch of the helium shortage. The bureau received dozens of inquiries from the AEC, the DOD, the Weather Bureau, defense contractors such as General Electric and Westinghouse, and private consumers complaining about the inability of helium distributors to meet their demands. Throughout the crisis, helium officials established a moratorium on the sale of helium for advertising, toy balloons, and any other non-national defense justifications. Helium orders from corporate giants such as the Walt Disney Company and Macy's were refused. The bureau even turned down a request from President Dwight D. Eisenhower's re-election committee for helium to fill "a large 'Ike' balloon" during the 1956 campaign.

In anticipation of growing helium demands, the Bureau of Mines in 1954 hired Stone & Webster Engineering Corporation to investigate the helium shortage and what the requirements would be to meet demands. The firm concluded in a "secret" document that the bureau's helium plants could not meet defense contract demands after 1955. The following year, the bureau itself reviewed the helium program. At the heart of the debate to meet the booming demand was whether helium production required continued exclusive government control or whether it could be turned over to private helium companies. The Bureau of Mines concluded that "as the sole producer of the Free World's helium supply for more than 30 years, the Bureau of Mines . . . has vital responsibility which it will fail to meet unless prompt action is taken." Although "the private enterprise system . . . is the backbone of our economy . . . the production of helium is unique, and the national interest is so paramount that a continuation of the Bureau's helium program is imperative." In other words, only the expansion of the government-operated helium program could meet the immediate Cold War demands.

The government had the technology and production capabilities to meet the challenge, and the bureau, in response to demand, had reorganized its program by establishing the Helium Activity divisions of helium production, engineering, gas fields operations, research, and administration under its umbrella. In that same report, the bureau also recommended a more systematic, congressionally mandated program of conservation or "stockpiling" of the strategic gas.

The bureau's immediate remedy was to expand facilities at the Exell plant; when the work was completed in June 1957, the plant had an additional 150 mmcf of production capacity. The bureau installed a new carbon dioxide removal system and an upgraded nitrogen expander. In the meantime, the bureau worked through legal negotiations to build a new plant at Keyes, Oklahoma, which began productivity in August 1959.

Helium Conservation

Even with the expansion at Exell and the new Keyes plant on line, Helium Activity officials realized the government could not meet the escalating demands for helium. The helium conservation program resulted. On October 1, 1957, O. Hatfield Chilson, undersecretary of the Interior, "appointed four subcommittees to study and report to him by November 1 … on certain specific phases of a program to conserve helium." Subcommittee III concluded that twelve new plants, in addition to the Keyes plant, would be necessary to meet helium demands through 2000. If the plants were not built and private industry failed to construct new plants, the subcommittee warned, billions of cubic feet of helium would be lost into the atmosphere. The bureau's practice of storing crude helium in the Cliffside field already had proved to be effective from 1954 to 1957 when 58 mmcf of 88 mmcf of helium were withdrawn during the shortage. This stockpile would be exhausted within the next two or three years, however, unless new plants were built. Initially, the bureau called for a 32.5 billion cubic feet conservation storage program, but then increased the figure to 56 billion cubic feet.

The Helium Policy Working Group also discussed the possibility of permitting the Department of the Interior to enter into contracts with private companies to purchase helium for the national defense program. The subcommittee decided that the helium conservation program should allow private companies to submit proposals for construction of new plants. Once the private companies began producing helium, the bureau would purchase the helium for storage at the Cliffside facility. The subcommittee suggested "that the most satisfactory form of private participation would involve selling all helium produced to the Government under stipulated conditions…" After eleven months of investigation and deliberation, the Department of the Interior announced on August 19, 1958, with President Eisenhower's approval, that it would propose legislation for a helium conservation program. The ultimate result was the Helium Conservation Act of 1960.

During the next four decades, the helium conservation program shifted the principal focus of helium production from the federal government to private industry. Private investors constructed more than fourteen new plants to meet the growing demands, especially during the 1960s. Eventually, the proficiency of the private producers forced Congress to pass the Helium Privatization Act of 1996. This legislation ended the 80-year federal program.

Conclusion

The federal government created and maintained the helium industry for most of the twentieth century. Like other strategic minerals such as copper and uranium, helium became a principal national defense element: first, as a lifting gas for naval dirigibles; then as a cooling agent for nuclear and atomic research and development; as an inert gas shield to weld titanium and zirconium rockets; and throughout the century for medical purposes. Foremost, the federal government viewed helium as a strategic element in the atomic age. Because the United States maintained a monopoly on helium for many decades, government officials believed helium gave the nation an edge in atomic science and the space race.

Likewise, the federal government developed the cryogenic technology necessary to separate chemists and engineers devised the super cooling processes that allowed for the production of helium, especially for lifting gas for dirigibles. In the post-World War II era, these same men improved the cryogenic process, implementing charcoal adsorption in the late 1940s. By this time, they already knew the main principles for producing helium. For the remainder of the century, helium scientists focused on making their helium production facilities more efficient on a larger scale. In the end, the helium program served admirably in providing the helium necessary to facilitate the development of the nation's military industrial complex during the world wars and in the fight to contain communism during the Cold War. Private helium companies were able to use that technological achievement to replace the federal program at the end of the twentieth century.

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